THE ASSOCIATION BETWEEN CIGARETTE SMOKING CESSATION AND GESTATIONAL WEIGHT GAIN

by

Katya Giovannetti

BA, University of Puerto Rico, Puerto Rico, 2003

MPH, University of Medicine and Dentistry of New Jersey, 2006

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This thesis was presented

by

Katya Giovannetti

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and approved by

Thesis Advisor:
Kristen J. Mertz, MD, MPH
Assistant Professor
Department of Epidemiology
Graduate School of Public Health
University of Pittsburgh

Thomas J. Songer, PhD
Assistant Professor
Department of Epidemiology
Graduate School of Public Health
University of Pittsburgh

Ada O. Youk, PhD
Assistant Professor
Department of Biostatistics
Department of Epidemiology
Graduate School of Public Health
University of Pittsburgh

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Katya Giovannetti, MS

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Women with excess gestational weight gain (GWG) have an increased risk of negative reproductive outcomes and major knowledge gaps remain in our understanding of specific causes of excess GWG. Maternal cigarette smoking is not only one of the most important modifiable risk factors for a variety of pregnancy outcomes, but smoking cessation is also a possible predictor for excess GWG. This study's objective was to examine for the first time the association between smoking cessation at different time points during pregnancy and excess GWG among 124,807 women in Pennsylvania, while taking racial/ethnic differences into account. The data are from Pennsylvania (PA) 2008 birth records. Results from our logistic regression analyses show that after adjusting for covariates, all quitters were at a higher risk of excess GWG as compared to non-smokers. Women who quit prior to pregnancy were 56% more likely to gain excessive weight as compared to non-smokers (OR = 1.56, 95% CI: 1.46, 1.66), whereas women who quit later on during pregnancy had a higher risk for excess GWG compared to non-smokers (OR = 1.46, 95% CI: 1.23, 1.70 for 1st trimester quitters; OR = 1.44, 95% CI: 1.23, 1.69 for 2nd trimester quitters). We found an interaction between race/ethnicity and smoking status in predicting excess GWG ($\chi^2_{(8)} = 16.5$, $p = 0.03$) suggesting that the association between smoking cessation and excess GWG differs by race/ethnicity. These findings are of great public health importance since they emphasize the need for individualized attention to

smoking habits from health care professionals so that pregnant women can successfully gain weight within their respective recommended range.

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PREFACE

A number of people have helped make this Thesis possible. I would like to acknowledge my Thesis Committee (Dr. Kristen J. Mertz, Dr. Thomas J. Songer, & Dr. Ada O. Youk) and my family, who provided me with the opportunity and encouragement to explore these ideas. I would like to give special thanks to Lori S. Smith for her constant help and understanding. Further thanks goes to Dr. Lisa M. Bodnar for providing me with the appropriate outcome definition for adequacy of gestational weight gain (GWG) and access to Pennsylvania (PA) 2008 birth records.

1.0 INTRODUCTION

Appropriate gestational weight gain (GWG) ensures adequate nourishment for the developing fetus and it is considered a significant predictor of maternal and neonatal health outcomes. Literature suggests that both excess and inadequate gestational weight gains (GWG) are associated with adverse pregnancy outcomes (IOM, 2009; Viswanathan, Siega-Riz, Moos, Deierlein, & Mumford, 2008). However, major knowledge gaps remain in our understanding of specific risk factors, such as smoking, on GWG and whether or not there are racial differences. In this paper, we explore the relationship between maternal cigarette smoking cessation and excess GWG and examine for the first time whether race/ethnicity modifies this relationship.

2.0 BACKGROUND AND SIGNIFICANCE

2.1.1 Gestational weight gain guidelines

In 1990, the Institute of Medicine (IOM) developed guidelines for appropriate GWG. These guidelines were reexamined by the IOM in 2009 because there was new evidence of additional adverse pregnancy outcomes associated with inappropriate GWG, and the population of U.S. women had become more ethnically diverse, heavier, and more likely to gain excess weight throughout pregnancy (IOM, 2009). According to the 2009 IOM guidelines, optimal GWG depends on prepregnancy body mass index (BMI), as shown in Table 1 below.

Table 1. Gestational Weight Gain Guidelines

Pre-Pregnancy BMI (kg/m^2)	**Recommended Total GWG at Term in lbs & (kg)**
Underweight (BMI < 18.5 kg/m^2)	28 to 40 lbs (12.5 – 18.5 kg)
Normal-weight (BMI 18.5 – 24.9 kg/m^2)	25 to 35 lbs (11.5 – 16.0 kg)
Overweight (BMI 25.0-29.0 kg/m^2)	15 to 25 lbs (7.0 – 11.5 kg)
Obese (BMI ≥ 30 kg/m^2)	11 to 20 lbs (5.0 – 9.0 kg)

Inadequate and excessive GWG can be defined as gaining weight below or above these specified IOM recommendations, respectively. Women with excess GWG are at an increased risk of gestational diabetes (Saldana, Siega-Riz, Adair, & Suchindran, 2006), cesarean delivery (Dietz, Callaghan, Cogswell, Morrow, Ferre, & Schieve, 2006), postpartum weight retention (Dietz et al., 2006), and having a baby who is large for gestational age (LGA) (Viswanathan et al., 2008). On the other side of the spectrum, inadequate GWG is associated with preterm birth and small for gestational age (SGA) (Hellerstedt, Himes, Story, Alton, & Edwards, 1997; Rasmussen, 2009).

2.1.2 Predictors of gestational weight gain

Gestational weight gain is influenced by a variety of physiological, psychological, behavioral, family, socio-cultural, and environmental factors (IOM, 2009). These predictors of GWG can be divide into two different categories, those maternal factors that are fixed (non-modifiable) at conception (e.g., race, age, and parity) and those that can be modified (e.g., diet, physical activity, smoking and prepregnancy BMI). There are specific factors that are considered to be the most significant determinants of total amount of weight gain during pregnancy (IOM, 2009), including modifiable factors such as pre-pregnancy BMI, dietary intake and physical activity, non-modifiable factors such as age, and medical conditions such as hyperemesis gravidarum (extreme, persistent nausea and vomiting during pregnancy unrelated to other medical conditions) and anorexia (IOM, 2009). There is consensus that more research is needed on other important determinants such as race/ethnicity and modifiable factors such as smoking (IOM, 2009).

Pre-pregnancy body mass index (BMI) is inversely related to GWG (IOM, 2009). Various large epidemiological studies, including one with a sample size of 2.3 million women (Voigt, Straube, Schmidt, Pildner von Steinburg, & Schneider, 2007), found that in general those women with pre-pregnancy obesity were more likely to gain less weight during pregnancy than overweight and normal-weight women (Chu, Callaghan, Bish, and D'Angelo, 2009; Voigt et al., 2007). But the IOM reports that excessive GWG is also increasing among obese and overweight women (IOM, 2009). The Pregnancy Risk Assessment Monitoring System (PRAMS) collects national data on GWG. Data from PRAMS shows that in 2003 the mean GWG among underweight and normal-weight women was within the recommended range; whereas, the mean GWG among overweight and obese women was higher than recommended (IOM, 2009; Dietz et al., 2006). Approximately 20% of underweight and 38% of normal-weight women gained excessively; the same data showed that 63% of overweight women and 46% of obese women gained excess GWG (IOM, 2009; Dietz et al., 2006). The greater likelihood of excess GWG among heavy women represents a major public health issue because the prevalence of pre-pregnancy obesity has increased from 1993 through 2003 (Kim, Dietz, England, Morrow, & Callaghan, 2007). This means that the number of women at increased risk for excess GWG and reproductive complications has also increased. Because obesity puts women at a higher risk for adverse pregnancy outcomes when their weight increases during pregnancy, it is important to monitor weight gain during pregnancy among these obese women.

Among other modifiable factors related to GWG are diet, physical activity, and smoking habits. For example, women who have a low energy dietary intake (Olson & Strawderman, 2003; Bergmann, Flagg, Miracle-McMahill, & Boeing, 1997; Deierlein, Siega-Riz, & Herring, 1998),

who exercise rigorously (Clapp & Little, 1995; Haakstad, Voldner, Henriksen, & Bo, 2007) or smoke (IOM, 2009) during pregnancy, are more likely to have inadequate GWG or gain less weight compared to their counterparts. Among non-modifiable risk factors, younger age relates to excessive GWG (Howie, Parker, & Schoendorf, 2003; Hediger, Scholl, Belsky, Anees, & Salmon, 1990; Scholl, Hediger, Ances, Belsky, & Salmon, 1990; Stevens-Simon, Nakashima, & Andrews, 1993), whereas older women are more likely to have inadequate GWG. There is less evidence regarding racial/ethnic disparities in GWG (IOM, 2009). Some studies suggest that black women are more likely to gain inadequate weight compared to white women (Caulfield, Witter, & Stoltzfus, 1996; Chu et al., 2009), whereas non-Hispanic white and Hispanic women have an increased risk for excess GWG (IOM, 2009).

Finally, certain medical characteristics related to the mother can greatly impact GWG (IOM, 2009). For example, maternal medical conditions such as depression (Bodnar, Siega-Riz, Simhan, Himes, & Abrams, 2009; Hickey, Cliver, Goldenberg, McNeal, & Hoffman, 1995; Siega-Riz & Hobel, 1997), physiological stress (Picone, Allen, Schramm, & Olsen, 1982; Brawarsky et al., 2005; Orr et al., 1996), anorexia nervosa (Kouba, Hallstrom, Lindholm, & Hirschberg, 2005) and hyperemesis gravidarum (Gross, Librach, & Cecutti, 1989; Goodwin, Montoro, & Mestman, 1992; Vilming & Nesheim 2000; Bailit, 2005) have been related to inadequate GWG, some found that depression is also associated with excessive GWG (Webb, Siega-Riz, & Dole, 2009; Casanueva, Labastida, Sanz, & Morales-Carmona, 2000).

2.1.3 Maternal cigarette smoke exposure and gestational weight gain

In the United States, 13% of women reported smoking during the last three months of their pregnancy (Centers for Disease Control and Prevention [CDC], 2004). Estimates as high as 17.8% for American Indian or Alaska Native women, 19% for teenagers (18-19 years) and women in their early twenties, and 20% for women with less than a high school education have been reported (Martin, Hamilton, Sutton, Ventura, Menacker, Kirmeyer, & Mathews, 2007).

Maternal cigarette smoking is considered to be one of the most important modifiable risk factors for a variety of reproductive outcomes including intrauterine growth retardation (IUGR), spontaneous abortion, preterm birth, placental complications, stillbirth, and sudden infant death syndrome (SIDS) (Surgeon General, 2001; Haworth, Ellestad-Sayed, King, & Dilling, 1980; Papoz, Eschwege, Pequignot, Barrat & Schwartz, 1982; Muscati, Mackey, & Newsome, 1988; Wolff, Portis, & Wolff, 1993; Groff, Mullen, Mongoven, & Burau, 1997). Smoking is also believed to be associated with excess GWG, but the literature is inconclusive (IOM, 2009).

Prior to the development of the 1990 Institute of Medicine's guidelines for GWG there was epidemiological evidence suggesting that smoking during pregnancy is associated with low total GWG (defined as the difference between weight at delivery and weight prior to pregnancy) (Rush, 1974; D'Souza, Black, & Richards, 1981; Davies, Gray, Ellwood, & Abernethy, 1976; Dawes & Grudzinskas, 1991). More recent studies have found that smoking is associated with inadequate GWG (defined as gaining weight below IOM recommendations) (Mongoven, Dolan-Mullen, Groff, Nicol, & Burau, 1996; Groff et al., 1997; Hellerstedt et al., 1997; Olson & Strawderman, 2003; Furuno, Gallicchio, & Sexton, 2004; Wells, Schwalberg, Noonan, & Gabor,

2006) but also that smoking cessation is related to excess GWG (defined as gaining weight above IOM recommendations) (Favaretto et al., 2007; Mongoven et al., 1996; Groff et al., 1997; Adegboye, Rossner, Neovius, Lourenco, & Linne, 2009). Other studies have shown no association between smoking during pregnancy and GWG (May, 2007; Garn, Hoff, & McCabe, 1979; Chasan-Taber et al., 2008). For instance, Chasan-Taber et al. (2008) found no statistically significant differences in GWG between smokers and non-smokers among 770 Hispanic prenatal care patients in Western Massachusetts (Chasan-Taber et al., 2008). The lack of association may be due to different smoking patterns among their study population (Hispanic pregnant women) as compared to non-Hispanic white populations (Chasan-Taber et al., 2008). For example, only 0.3 percent of their Hispanic participants smoked more than 1.5 packs per day (Chasan-Taber et al., 2008), which is significantly less than the 21% of pregnant heavy smokers reported in the US by the Centers for Disease Control and Prevention (CDC, 2004). Additionally, no adjustments for gestational age were made, thus their results regarding the smoking-GWG association were most likely confounded by length of gestation. A rationale for our study was to add to this literature by examining the association between smoking cessation and excess GWG while adjusting for gestational age and prepregnancy BMI and by having a better representation of Hispanic and non-Hispanic women in our population.

Smoking is directly associated with a shorter gestation (Kyrklund-Blomberg & Cnattingius, 1998; Secker-Walker & Vacek, 2002), and length of gestation determines amount of weight gain during pregnancy. Thus, adjusting the association between total GWG and smoking during pregnancy for gestational age is important. There are discrepancies in GWG measurements, and whether or not they are adjusted for gestational age, among the numerous

studies conducted to assess this association. The majority have studied total gestational weight gain, which is measured by calculating the difference between maternal weight at delivery and prepregnancy weight (Rush, 1974; Davies et al., 1976; D'Souza et al., 1981; Dawes & Grudzinskas, 1991; Mongoven et al., 1996; Groff et al., 1997; Hellerstedt et al., 1997; Olson & Strawderman, 2003; Furuno et al., 2004; Wells et al., 2006; Favaretto et al., 2007; May, 2007; Chasan-Taber et al., 2008; Adegboye et al., 2009; Walker, Hoke, & Brown, 2009). However, only 9 of these 15 studies adjusted for gestational age either while calculating total GWG or controlling for it in their statistical analyses (Rush, 1974; Dawes & Grudzinskas, 1991; Mongoven et al., 1996; Groff et al., 1997; Olson & Strawderman, 2003; Furuno et al., 2004; Favaretto et al., 2007; May, 2007; Adegboye et al., 2009).

2.1.4 Smoking cessation

Attention has been devoted to the study of GWG differences among smokers and non-smokers, but little attention has been paid to those women who ceased smoking (Adegboye et al., 2009). There are a few studies that examined the effects of smoking cessation on total GWG (Mongoven et al., 1996; Groff et al., 1997; Favaretto et al., 2007; Adegboye et al., 2009). Both Mongoven et al. (1996) and Groff et al. (1997), randomly selected white non-Hispanic pregnant women from Project PANDA (Parents and Newborns Developing and Adjusting), a randomized clinical trial to sustain prenatal smoking cessation after delivery (Mongoven et al., 1996; Groff et al., 1997). Mongoven et al. (1996), only included 238 smokers and recent quitters (before 14 week's gestation), and found that quitters were more likely to gain excess GWG as compared to smokers (RR: 1.74; 95% CI: 1.21, 2.51) (Mongoven et al., 1996). Meanwhile, in 1997 Groff et al. included 341 non-smokers, smokers, and quitters (before 14 week's gestation),

to study the effects of maternal smoking status on prenatal weight gain and infant birthweight. Their results were similar to those presented by Mongoven and colleagues which included a statistically significant association between smoking cessation and excess GWG (Groff et al., 1997). Both studies adjusted for gestational age. Mongoven et al. (1996) found a significant association between excess GWG and smoking cessation even after stratifying weight gain by gestational week at last prenatal visit (Mongoven et al., 1996).

Groff et al. (1997) found that weight gain differences associated with smoking cessation became noticeable towards the 2nd trimester (Groff et al., 1997). Their results showed that during the 2nd trimester women who stopped smoking (before 14 week's gestation) were 2.57 times as likely as those who never smoked to have gained more weight (Groff et al., 1997). Additionally, these women who ceased smoking continued to gain more weight during the 3rd trimester as compared to both smokers and never smokers, specifically women who ceased smoking during pregnancy were 4.31 times as likely as smokers and 1.25 times as likely as never smokers to have gained more weight in their last trimester (Groff et al., 1997). While investigators adjusted for gestational age these results can only be generalized to non-Hispanic, non-diabetic, white women with a relatively good income.

A more recent study found similar results. A study in Stockholm, Sweden, investigated whether or not smoking cessation at the beginning of pregnancy had any effect on total GWG (Adegboye et al., 2009). Results showed that women who quit smoking were significantly more likely to gain excess weight as compared to those women who continued smoking and those who never smoked ($p < 0.001$), in addition to concluding that smoking cessation in early pregnancy

doubles the likelihood of gaining weight above the IOM recommendations (OR: 2.0; 95%CI: 1.4-3.0) (Adegboye et al., 2009).

The authors note a few limitations. For example, smoking status was assessed retrospectively at 6 months post-partum and due to the well known negative effects of smoking during pregnancy women may have underreported their exposure or may have been prone to recall bias. Subsequently, underreporting smoking might lead to exposure misclassification bias which might underestimate their results. Additionally, their results can only be generalized to Caucasian women. Adegboye and colleagues discussed the idea that when women quit smoking during pregnancy might have different effects on GWG. Due to a small sample size they were unable to stratify their analysis according to the time of quitting (e.g. beginning or end of pregnancy). Understanding how smoking cessation affects GWG is extremely important because quitting may have different effects on GWG depending on timing (Favaretto et al., 2007). Additionally, knowing the impact of smoking cessation on GWG, and the differences in the risk for excess GWG associated with quitting at different time points during pregnancy could provide physicians with additional information to improve their recommendations to their pregnant patients.

To our knowledge there is only one study to date examining smoking cessation at different time points during pregnancy and its association to excess GWG. Favaretto and colleagues were able to analyze time of quitting in a prospective cohort of 5,564 pregnant women in Brazil. The authors found that the risk of gaining excess GWG for women who ceased smoking was 1.20 times greater (RR: 1.20; 95% CI: 1.05-1.37) than that for non-smokers

(Favaretto et al., 2007). In this population, the risk for excess GWG was greater the earlier women quit smoking during pregnancy. For example, for those who ceased smoking after conception the risk for excess GWG was 34% greater as compared to those who never smoked (RR: 1.34; 95% CI: 1.10-1.63) and for those who ceased smoking < 6 months prior to conception the risk for excess GWG was 14% greater as compared to those who never smoked (RR: 1.14; 95% CI: 0.94-1.38) (Favaretto et al., 2007). Unfortunately, these results can only be generalized to Brazilian pregnant women whose lifestyle, nutrition, and health care access probably differs from women in the US.

2.1.5 Race and ethnicity as an effect modifier

The Institute of Medicine indicates that there are "racial and ethnic disparities in nearly all gestational weight-related predictors and outcomes reviewed"; specifically, they denote racial differences in pre-pregnancy weight, GWG, and smoking status throughout pregnancy (IOM, 2009). Non-Hispanic black women have higher prepregnancy weight and gain more weight throughout pregnancy as compared to their non-Hispanic white counterparts (Kim et al., 2007). Hispanic women, although more likely to have excess GWG (IOM, 2009), smoke less than non-Hispanic black and non-Hispanic white pregnant women (Chasan-Taber et al., 2008). It is important to replicate these studies regarding smoking cessation and excess GWG while taking these racial/ethnic differences into consideration. These analyses are only possible among a large and racially/ethnically diverse sample of women, and to date have not been performed.

Our study had the sample size to examine for the first time the association between smoking cessation at different time points during pregnancy and excess GWG (adjusted for

gestational age at delivery) while taking racial/ethnic differences and prepregnancy BMI into account. The goal this study was to investigate differences in the adequacy of GWG among smokers, nonsmokers, and quitters in a large population-based and ethnically diverse cohort of pregnant women in Pennsylvania.

2.1.6 Study objective and specific aim

The overall objective of this study was to explore the adequacy of gestational weight gain among 124,807 women who had different smoking cessation patterns during pregnancy. In particular, the main focus of our study was to investigate how smoking cessation at different time points during pregnancy was associated with excess GWG after adjusting for prepregnancy BMI and gestational age at delivery, and whether or not the association differed by race/ethnicity.

The specific aim of this study was to explore the adequacy of GWG between non-smokers (n = 96,714), smokers (n = 16,180), women who quit smoking prior to pregnancy (n = 7,675), women who quit smoking during their 1st trimester (n = 3,034), and women who quit smoking during their 2nd trimester (n = 1,204). We specifically wanted to answer the following questions: Is excess GWG more common among quitters than non-smokers? Is there any difference in the risk of excess GWG between women who quit smoking prior to pregnancy as compared to those who quit during their 1st or 2nd trimester? Is the association between smoking cessation and excess GWG modified by race/ethnicity?

3.0 METHODS

3.1.1 Study design and population

The data are from Pennsylvania (PA) 2008 birth records. There were a total of 140,165 singleton, liveborn infants. A total of 11,386 of these births were excluded due to lack of information on prepregnancy weight, weight at delivery, height, gestational age, or implausible weight gain at the end of pregnancy (weight loss of ≥ 40 lbs and weight gain > 80 lbs). Of 128,779 women included in our sample, 3,972 women were additionally excluded due to incomplete information on smoking status. Thus, the final sample size was 124,807 women. There were no major differences in the distribution of maternal and socio-demographic factors between women who were excluded and those included in the study.

3.1.2 Assessment of outcome variable: Adequacy of GWG

Information on prepregnancy weight and height on the PA birth record was assessed through maternal self-reports at delivery or immediately after delivery. We used these data to calculate pregravid body mass index (BMI) [self-reported prepregnancy weight (kg) / self-reported height (meters)^2]. We then created prepregnancy BMI categories according to the accepted definition of obesity: BMI <18.5 = underweight; BMI 18.5-24.9 = normal-weight; BMI 25.0-29.9 = overweight; and BMI ≥ 30.0 = obese. Maternal weight at delivery and gestational

age on the birth record were ascertained from maternal medical records as the last measured weight at or before admission to labor and delivery.

The adequacy of GWG was ascertained using the following definition: "the ratio of *observed* gestational weight gain to *expected* (recommended) gestational weight gain at the gestational age of delivery multiplied by 100", which has been previously described (Bodnar et al., 2009; Bodnar, Siega-Riz, Arab, Chantala, & McDonald, 2004; Siega-Riz, Adair, & Hobel, 1996). *Observed* GWG was calculated as the difference between weight at delivery (in pounds) and the self-reported prepregnancy weight (weight immediately before pregnancy) (in pounds). *Expected* GWG was calculated as 100% of the 2009 IOM recommendations at the gestational age of delivery (IOM, 2009). The following equation, previously described by Bodnar et al. (2009), was used to define *expected* GWG: "*Expected* GWG = recommended 1st trimester total weight gain + (gestational age at weight measurement at or before delivery - 13 wk) × recommended rate of gain in 2nd and 3rd trimesters. The assessment of these expected weight gains automatically adjusts GWG for gestational age.

The IOM (2009) recommended a lower and upper value of total gestational weight gains for each prepregnancy BMI group. We divided the lower and upper limits of these recommended weight gain ranges by the previously calculated *expected* weight gain at 40 weeks gestation for each prepregnancy BMI group and multiplied by 100 (Bodnar et al., 2009). For example, an underweight woman is recommended to gain between 12.5 and 18.5 (kg) of weight during pregnancy and her expected weight gain at 40 weeks (based on the *expected* weight gain equation) should be 15.77 kg. Therefore, in our study the ranges of recommended weight gain

for this particular woman were (12.5/15.77)*100 = 79% of recommended weight gain and (18.5/15.77)*100 = 114% of the IOM recommendation. Women whose weight gain was less than their respective lower cutoff of recommendations gained inadequate weight; women whose weight gain was greater than the upper cutoff of recommendations gained excess weight; and women whose weight gain was within the recommended rage gained adequate weight (Bodnar et al., 2009).

3.1.3 Assessment of exposure variable: Smoking status

After delivery, mothers are asked to fill out a short questionnaire called the "Mother's Worksheet" to gather information included in the birth certificate. Here women were asked their age, marital status, race/ethnicity, whether they received WIC food, etc. In addition, women were asked how many cigarettes they smoked on an average day during each of the following time periods: (1) three months before pregnancy; (2) first three months of pregnancy; (3) second three months of pregnancy; and (4) last three months of pregnancy.

We created the following smoking status categories and grouped women into these mutually exclusive categories: "Non-Smokers" (includes women who did not smoke prior to pregnancy and during the 1st, 2nd, and 3rd trimesters) (n = 96,714); "Smokers" (includes women who smoked at least 1 cigarette per day prior to pregnancy and during the 1st, 2nd, and 3rd trimesters) (n = 16,180); "Pre-pregnancy Quitters" (includes women who smoked at least 1 cigarette per day prior to pregnancy but quit before pregnancy and did not smoke during the 1st, 2nd, and 3rd trimesters) (n = 7,675); "1st Trimester Quitters" (includes women who smoked at least 1 cigarette per day prior to pregnancy and during their 1st trimester but did not smoke

during the 2nd and 3rd trimesters) (n = 3,034); and "2nd Trimester Quitters" (includes women who smoked at least 1 cigarette per day prior to pregnancy, and during the 1st and 2nd trimesters but did not smoke during the 3rd trimester) (n = 1,204). Out of a total of 128,779 women that are part of our original sample 3,972 were excluded because they had missing information on smoking or were women who quit prior to or during pregnancy but relapsed at some point during pregnancy.

3.1.4 Assessment of covariates

Maternal age was categorized into the following groups: less than 20, 20 to 29, 30 to 39, and 40-49. Women older than 49 years were excluded. The categories for educational status included 'less than high school', 'high school diploma or GED', 'some college and/or college degree', and 'graduate school'. Women were categorized as married or single, and whether they received WIC food during pregnancy. Participants were also asked about their previous live births and were categorized into having 'none', 'one', or 'more than 2'. Women self designated their race and were categorized into these race/ethnicities: 'Non-Hispanic White', 'Non-Hispanic Black', 'Non-Hispanic Asian', 'Non-Hispanic Other' and 'Hispanic'.

3.1.5 Data analysis

All data analysis was performed using STATA software version 11. We calculated percentages for each weight gain category (inadequate, adequate or excessive), according to each factor/variable. Additionally, we calculated frequency distributions of smoking status categories according to each factor/variable. Pearson's Chi-Square tests were used to test for the individual

association between GWG and smoking status, and all other covariates. We then examined the strength of these associations with logistic regression analyses.

We limited our logistic regression analyses to women with adequate or excess GWG because our main study objective was to assess the association between smoking cessation and excess GWG while adjusting for covariates. We fitted individual binary logistic regressions to calculate crude odds ratios (ORs) and their respective 95% confidence intervals (CIs) to examine the unadjusted associations between excess GWG and smoking status, and between excess GWG and all other covariates. For our multivariate models, we first examined the full model including excess GWG, smoking status, and all other covariates. Adjusted ORs and their 95% CIs for smoking status and all other covariates were also ascertained. To obtain a reduced (parsimonious) model, we dropped any covariates that were not statistically significantly associated with excess GWG (p value > .05) and re-assessed the association. Finally, we added two interaction terms to the reduced model, one for race/ethnicity and smoking and one for prepregnancy BMI and smoking, and tested whether or not they predicted excess GWG. We used the likelihood ratio test and examined if the reduced model as a whole was statistically significant in predicting excess GWG. As part of the logistic regression diagnostics we performed a global test of goodness of fit using the Hosmer-Lemeshow test (Hosmer & Lemeshow, 1989) and additionally tested for any specification errors while performing the regression equation specification error test (RESET) (Ramsey, 1969; Sapra, 2005) to be certain that our reduced model was not misspecified.

We then analyzed our data using the reduced model while stratifying by race/ethnicity and then by prepregnancy BMI. We stratified the analysis to assess whether or not race or prepregnancy BMI were modifying the effect of smoking on excess GWG.

4.0 RESULTS

In the 2008 PA cohort approximately 24% and 21% of women were categorized as overweight and obese prior to pregnancy, respectively, while 4% were classified as underweight. About 62% of women were ≤ 29 years and more than half (58%) had 1 or more prior live births. Most women were non-Hispanic white (71%) while 14% were non-Hispanic black and 9% were Hispanic.

The distribution of GWG was as follows: 19% of women had inadequate GWG, 23% gained adequately, and 58% had excess GWG (Table 2). Overweight women were most likely to have excess GWG (71%), while underweight women were the least likely to gain in excess (37%). Gaining excess weight during pregnancy was more frequent than gaining adequately and inadequate GWG regardless of their smoking status. The percentage of smokers who gained excessively was slightly less (54%) than the percentage of non-smokers who had excess GWG (57%) and the percentage of quitters (including smoking cessation at all three time points) who had excess GWG was much greater than both smokers and non-smokers. Smoking cessation throughout pregnancy was associated with excess GWG; more women who quit smoking prior to pregnancy (70%), who quit during their 1st trimester (68%), and who quit during their 2nd trimester (64%) had excess GWG as compared to 54% of smokers (χ^2 = 893.72; p < .001). Additionally, our results show that the earlier you quit smoking the higher the frequency of excess GWG.

As shown in Table 2, women with no prior live births were more likely have excess GWG while those with 2 or more prior live births were more likely to gain inadequately. The percentage of women with excess GWG was greater for each age group than the percentage of women with inadequate and adequate GWG. Within each educational category the percentage of excess GWG was higher than the percentage of women gaining inadequate and adequate weight. A greater percentage of women receiving aid from the Women, Infants and Children program (WIC) during pregnancy gained weight inadequately (22%) as compared to 17% of women not receiving these services. Excess GWG was most common for both groups of women. Excess GWG was also more common among both married and single women than adequate GWG.

Excess GWG was more frequent than adequate and inadequate weight gain across all racial/ethnic groups. When comparing women within their respective racial/ethnic groups, non-Hispanic white (59%) and non-Hispanic black women (59%) had a slight increased frequency for excess GWG compared to 53% of Hispanics.

Table 3 shows the distribution of prepregnancy BMI and maternal and socio-demographic factors according to smoking status. Approximately 13% of women reported smoking throughout pregnancy and 6% reported quitting before pregnancy; fewer women quit during their 1st trimester (2.4%) and 2nd trimester (1.0%). Quitting prior to pregnancy was more common than quitting during the 1st and 2nd trimester within each prepregnancy BMI category. As expected, a higher percent of underweight women were smokers (21.3%) as compared to the frequency of smokers among normal-weight (12.0%), overweight (12.4%), and obese (14.3%) women. Similarly, smoking cessation at any time point was more common among underweight women as compared to normal-weight, overweight, and obese women. More women with no prior births ceased smoking prior to pregnancy (8.3%) as compared to those who had 2 or more

births (3.7%). Women of a younger age (less than 29), with a high school degree, single, receiving WIC, and considered non-Hispanic white had a higher frequency of quitters at any time point than their counterparts.

Table 4 shows results from separate binary logistic regressions examining the crude associations between excess GWG, smoking cessation, and all other covariates. Smoking cessation increased the risk for excess GWG without adjusting for any covariates. Women who quit smoking prior to pregnancy were 64% more likely to experience excess GWG as compared to non-smokers (OR = 1.64, 95% CI: 1.55, 1.75), whereas those who quit during their 1st and 2nd trimester were 54% (OR = 1.54, 95% CI: 1.40, 1.69) and 46% (OR = 1.46, 95% CI: 1.26, 1.70) respectively, at a higher risk to have excess GWG as compared to non-smokers. In these crude analyses, prepregnancy BMI seemed to have the strongest association with excess GWG, with overweight and obese women being more than 4 times as likely as underweight women to have experienced excess GWG (OR = 4.67, 95% CI: 4.36, 5.00; OR = 4.45, 95% CI: 4.15, 4.77). Women with one or more prior live births, 30 years or older, or married were statistically significantly less likely to have gained excess weight during pregnancy as compared to women with no prior births, less than 20 years old, and single. Women with a higher education, not receiving WIC, and of non-Hispanic black race had a higher risk for excess GWG as compared to those with less than high school education, receiving WIC, and of non-Hispanic white race.

Results from the adjusted logistic regression analyzing the full model (model including smoking status and all covariates) are also shown in Table 4. After fitting this adjusted logistic regression we removed two covariates (WIC recipient and age) from the model because they were no longer statistically significantly associated with excess GWG. In Table 4 we can also see results from fitting the reduced model (model without age and WIC) to predict excess GWG.

After adjusting for other covariates, and removing age and WIC from the analysis, excess GWG remained statistically significantly associated with smoking cessation during all three time points; women who quit prior to pregnancy had a 56% higher risk for excess GWG as compared to non-smokers (OR = 1.56, 95% CI: 1.47, 1.67), and those who quit during their 1st trimester were 1.46 times as likely as non-smokers to experience excess GWG (OR = 1.46, 95% CI: 1.23, 1.70). In addition, 2nd trimester quitters were also more likely than non-smokers to have excess GWG (OR = 1.44, 95% CI: 1.23, 1.69). While all women who ceased smoking were at a higher risk of gaining excess GWG independent of the time their quit, our results show that the earlier women quit smoking the higher their risk for excess GWG as compared to non-smokers. Smokers' risk for excess GWG was slightly significantly higher as compared to non-smokers (OR = 1.05, 95% CI: 1.00, 1.10), the same was not true when examining the full model.

Results from the Hosmer-Lemeshow test indicated that our final reduced model was not adequate ($\chi^2_{(8)} = 36.06$, $p < 0.0001$). Meanwhile, results from the regression equation specification error test (RESET) were not statistically significant revealing that our final/reduced model is properly specified, that we have not omitted any relevant variables and that our link function is correctly specified.

When examining the univariate analyses both race/ethnicity and prepregnancy BMI were related to both smoking and excess GWG indicated by their statistically significant p values (e.g., $p < 0.0001$). Therefore, we added two interaction terms (race/ethnicity*smoking & prepregnancy BMI*smoking) to our final model and found that they were both statistically significantly associated with excess GWG, ($\chi^2_{(8)} = 16.5$, $p = 0.03$) and ($\chi^2_{(12)} = 43.4$, $p < 0.0001$) respectively, indicating that there is interaction between race/ethnicity and smoking and

prepregnancy BMI and smoking while predicting excess GWG. Stratified analyses of the final model by race/ethnicity and prepregnancy BMI are shown in Tables 5 and 6.

Stratifying by race showed that smoking cessation prior to pregnancy significantly increased the risk for excess GWG among all three racial/ethnic groups, non-Hispanic white, non-Hispanic black, and Hispanic (Table 5). Although smoking cessation during the 1st trimester increased the risk of excess GWG it was no longer statistically significant among non-Hispanic black (OR = 1.21, 95% CI: 0.91, 1.62) and Hispanic women (OR: 1.41, 95% CI: 0.98, 2.02) (Table 5). While continuing smoking throughout pregnancy among non-Hispanic white and black women did not statistically significantly increase the risk of excess GWG (which is true for the un-stratified results), Hispanic women who smoked had a 24% increased risk for excess GWG as compared to Hispanic non-smokers (OR 1.24, 95% CI: 1.01, 1.53) (Table 5).

Smoking cessation during all three periods was associated with a statistically significant higher risk for excess GWG among women with a "normal" and "overweight" prepregnancy BMI (Table 6). When comparing women who quit prior to pregnancy and during 1st trimester to non-smokers it seemed that the early quitters (prior to pregnancy) carried a higher risk for excess GWG as compared to non-smokers than women quitting during their 1st trimester. This was statistically significant for all women except those with prepregnancy obesity (Table 6). Results varied by prepregnancy BMI when comparing smokers to non-smokers and their risk for excess GWG, with statistically significant results only among normal-weight and overweight women (Table 6). As shown in Table 6, although smokers with a normal prepregnancy weight had a 12% increased risk for excess GWG as compared to non-smokers (OR = 1.12, 95% CI: 1.04, 1.19),

overweight smokers had a 13% decreased risk for excess GWG as compared to overweight non-smokers (OR = 0.87, 95% CI: 0.79, 0.97) (Table 6).

5.0 DISCUSSION

Overall, we found similar results to prior studies while using birth data from a large cohort of women with a good representation of non-Hispanic whites and Hispanics throughout the state of Pennsylvania. Only 51% of women in our sample were considered to have a "normal" BMI prior to pregnancy and only 26% experienced adequate gestational weight gain. This means that the majority of women in our sample gained below or above the range recommended by the IOM. Our results are consistent with prior findings in the United States which state that less than half of women gain adequately during pregnancy (IOM, 2009). Additionally, the strong relationship between pregravid BMI and total GWG found in our population is consistent with findings across studies (IOM, 2009; Cedergren, 2006; Nohr, Vaeth, Baker, Sorensen, Olsen, Rasmussen, 2008) including an article published by Abrams and Laros in 1986 (Abrams & Laros, 1986).

The prevalence of smoking in this population is very similar to nationwide statistics. Approximately 13% of our sample reported smoking prior to and throughout pregnancy, while data from 26 states (not including PA) collected by the Pregnancy Risk Assessment and Monitoring System indicate that 13% of women reported smoking during the last three months of their pregnancy in 2004 (Martin et al., 2007). This similarity is to be expected because PRAMS collected data from birth certificates and therefore smoking status was assessed while using a similar methodology to ours.

To our knowledge this study is one of the few, if not the only, to investigate smoking cessation at three different time points throughout pregnancy (prepregnancy, 1st & 2nd trimesters) and its association to the adequacy of GWG among such a large, ethnically diverse population. Most published studies have been performed among predominantly small groups of white women. For example, in 2009 Adegboye et al. found in a sample of white European women that those who quit smoking were significantly more likely to gain excess weight as compared to those women who continued smoking and those who never smoked ($p < 0.001$), in addition to concluding that smoking cessation doubles the likelihood of gaining weight above the IOM recommendations in early pregnancy (OR = 2.0, 95%CI: 1.4, 3.0) (Adegboye et al., 2009). We found similar results in our much larger population.

Although it is well documented that there are racial differences in GWG (IOM, 1009) and smoking during pregnancy (IOM, 2009; Perreira & Cortes, 2006) only a few studies have examined racial/ethnic disparities in GWG (IOM, 2009), and even fewer studies have had the ability to stratify by race/ethnicity when analyzing the effects of smoking cessation on excess GWG (IOM, 2009). Typically, non-Hispanic black women are less likely to experience excess GWG as compared to non-Hispanic white and Hispanic women (Caulfield et al., 1996; Chu et al., 2009), whereas Hispanic women have a tendency to gain weight in excess (Chu et al., 2009). In addition, smoking during pregnancy is more prevalent among non-Hispanic white women as compared to non-Hispanic black and Hispanic women (Perreira & Cortes, 2006).

In contrast to past results (Chu et al., 2009), our study found that the percentage of Hispanic women who experienced excess GWG was smaller than the percentage of non-Hispanic white and non-Hispanic black women (Table 2). Whereas similar to prior studies (Perreira & Cortes, 2006), more non-Hispanic white women smoked than non-Hispanic black and Hispanic women in our study (Table 3). When examining both the crude and adjusted association between race/ethnicity and excess GWG, only non-Hispanic black women had a statistically significant increase in the risk for excess GWG as compared to non-Hispanic white women (Table 4).

Overall, our adjusted results show that smoking cessation during all three time points increased the risk for excess GWG. But, when stratifying by race/ethnicity we found that smoking cessation (at all three time points) was associated with an increased risk for excess GWG only among non-Hispanic white women, whereas smoking cessation during the 1st trimester did not increased the risk for excess GWG among non-Hispanic black and Hispanic women (Table 5), which confirms effect modification. Finally, while the literature suggests that smoking is associated with inadequate GWG (Mongoven et al., 1996; Groff et al., 1997; Hellerstedt et al., 1997; Olson & Strawderman, 2003; Furuno et al., 2004; Wells et al., 2006) and not necessarily with excess GWG, our stratified results show that among Hispanic women smoking also increased the risk for excess GWG, whereas this was not true for non-Hispanic white and black women (Table 5).

The literature suggests that while underweight women are more likely to have excess GWG and overweight and obese women tend to have inadequate GWG (IOM, 2009; Chu et al.,

2009; Voigt et al., 2007), recent evidence indicates that the prevalence of excess GWG among the already overweight and obese is increasing (IOM, 2009). Prepregnancy BMI has also been associated with smoking status (IOM, 2009). Our large sample size gave us the ability to stratify our analysis by prepregnancy BMI and examine whether or not the effects of smoking cessation on excess GWG depend on weight prior to pregnancy. Our stratified results presented in Table 6 show differences in the effect of smoking cessation on excess GWG across prepregnancy BMI strata. For example, after stratification we found that smoking cessation at all three time points increased the risk for excess GWG among normal-weight and overweight women but not among underweight and obese women (Table 6). Nevertheless, the risk for excess GWG associated with smoking cessation prior to pregnancy was greater among underweight and normal-weight women as compared to overweight and obese women (Table 6). Additionally, although smoking slightly increases the risk for excess GWG among normal-weight women, it reduces the risk among overweight women, while no association between smoking and excess GWG was found among underweight and obese women.

Overall, our results show that smoking cessation is associated with an increased risk of excess GWG as compared to women who do not smoke. We also show that there are racial/ethnic and prepregnancy weight differences modifying this effect. Having information on non-Hispanic black and Hispanic women, and the ability to stratify by prepregnancy BMI, does not only improve our capacity to generalize our results but it distinguishes our study from others while closing the gap in the literature concerning racial/ethnic disparities in GWG.

Results from the adjusted logistic regression of the final model indicate that smokers had a slightly, but not statistically significant, higher risk of excess GWG than non-smokers, which is consistent with previous findings (Adegboye et al., 2009; Favaretto et al., 2007). According to Favaretto et al. (2007) any reduction in the amount of smoking during pregnancy associates with an increased risk for additional weight gain (Favaretto et al., 2007). Therefore, this finding might represent smokers who decreased the amount of cigarettes during pregnancy and women who either ceased smoking prior to pregnancy (or early pregnancy) but relapsed. This could also explain the risk reduction of excess GWG among overweight smokers (Table 6) if the majority of these women were heavy smokers that did not decreased the amount of cigarettes smoked during their pregnancy.

Unfortunately, one of our limitations was the inability to examine differences in the risk of excess GWG associated with whether or not women relapsed back to smoking during their pregnancy. This is mostly due to measurement errors while defining a "relapse" category. In order to correctly categorize women into "relapse" we needed to have a good measurement of the frequency of smoking after cessation (e.g. how many consecutive days of smoking after quitting), and this information was unavailable to us.

Another potential limitation of this study is the lack of accurate data on prepregnancy BMI. Because prepregnancy BMI was ascertained by recalled weight and height it is possible to have some misclassification bias (Bodnar, Siega-Riz, Simhan, Diesel, & Abrams, 2010). Because we did not have the opportunity to quantify this bias we have no evidence of whether or not we were overestimating or underestimating our results.

Additional information that would have been useful to include in our analysis was women's dietary habits and physical activity. This is a limitation since there is evidence that both smoking and GWG are associated with dietary intake and physical activity (IOM, 2009). For example, there is evidence that women who quit smoking prior to or during pregnancy may also adopt other healthier lifestyles (Adegboye et al., 2009). Hence, it is possible that failure to adjust for these covariates may have affected our results.

Because the harmful effects of cigarette smoke and the pregnancy-related risks of smoking are well known it is possible to have some under-reporting of smoking habits in our sample which could have made our results susceptible to information and exposure misclassification bias. We are not only aware that in a clinical setting, such as prenatal care, cigarette smoke exposure may be underreported, but we are additionally concerned with the validity of self-reported smoking status and whether or not we correctly estimated its quantitative effect on GWG. An advantage of the study performed by Groff and colleagues (1997) was the use of urine cotinine (a nicotine metabolite) to validate smoking status among a randomly selected group of non-smokers and quitters (women who reported abstinence 29 days at the 28-week interview) (Groff et al., 1997), which improves their assessment of smoking status. The biological measurement of cotinine, ascertained from blood or urine, indicates the presence of nicotine which helps corroborate smoking status however we were unable to assess this. Future research should further examine the association between smoking cessation and excess GWG while gathering information on important confounders and assessing measurements such as cotinine that could help validate smoking status.

Due to the multitude of predictors of GWG it is challenging to know who is at a higher risk of excess GWG. The large number of variables included in our model is a possible explanation for the lack of fit in our final/reduced model, in addition to having such a large sample size. If we could better describe the population of pregnant women who are gaining excess weight we could help develop suitable and successful interventions. We had the opportunity to investigate an association between smoking cessation and excess GWG, which are both behavioral exposures with serious detrimental health effects. Furthermore, we had the ability to conclude there is some evidence of racial/ethnic differences modifying the association between smoking cessation and excess GWG. The high proportion of both smoking and excess GWG in pregnant women highlights the potential public health impact of these risk factors on adverse pregnancy outcomes and reiterates the importance of our findings. Given the fact that an increasing percentage of women of childbearing age in America keep moving towards overweight and obesity (IOM, 2009), and that approximately 23.2% of women in the US report smoking prior to pregnancy and 13% smoke during pregnancy (CDC, 2004), the IOM recommendations on targeting and monitoring excess GWG seem now more important than ever. This study could be used as a foundation for future research where detailed information on important confounders and additional, more valid, measurements on smoking status and prepregnancy BMI, might be available.

6.0 CONCLUSION

Our findings suggest that smoking cessation increases the risk for excess GWG depending on a woman's race/ethnicity and prepregnancy BMI. It is evident that women who smoke or who quit smoking are in need of individualized attention from their health care providers, as well as from other health care professionals within maternal health clinics throughout the US, so that they can successfully gain weight within their respective recommended range. The IOM advises that in order to help women stay within their recommended GWG range, health care providers should closely monitor their weight gain progress beyond the solely documentation of their weight gain between visits. They also recommend counseling these women about diet and physical activity. Our findings suggest that, among women who smoke, it would be beneficial to take into consideration their smoking patterns (e.g. smoking cessation prior to pregnancy, during 1^{st} or 2^{nd} trimester) in combination with their prepregnancy BMI and race/ethnicity, while implementing interventions with individualize advice that can help them gain weight adequately.

Both smoking and GWG are associated with various adverse pregnancy outcomes, which highlights the need for supportive measures to help control weight gain among pregnant women who quit smoking and those who continue.

APPENDIX

TABLES FROM RESULTS SECTION

Table 2. Adequacy of GWG[1] by smoking status & maternal/socio-demographic factors

Exposure & Covariates	Total N	Adequate GWG N (%)	Inadequate GWG N (%)	Excess GWG N (%)
Total	**128,779**	**29,806 (23.1 %)**	**24,577 (19.1 %)**	**74,396 (57.8 %)**
Smoking Status				
Non-Smokers	96,714	23,239 (24.0)	18,367 (19.0)	55,108 (57.0)
Smokers	16,180	3,564 (22.0)	3,829 (23.7)	8,787 (54.3)
Pre-pregnancy Quitters	7,675	1,373 (17.9)	946 (12.3)	5,356 (69.8)
1st Trimester Quitters	3,034	567 (18.7)	396 (13.0)	2,071 (68.3)
2nd Trimester Quitters	1,204	222 (18.4)	212 (17.6)	770 (64.0)
Unknown	3,972	841 (21.2)	827 (20.8)	2,304 (58.0)
Pre-pregnancy BMI[2]				
< 18.5 (Underweight)	5,486	2,159 (39.4)	1,301 (23.7)	2,026 (36.9)
18.5 - 24.9 (Normal)	65,659	18,733 (28.5)	12,815 (19.5)	34,111 (52.0)
25.0 - 29.9 (Overweight)	30,804	4,967 (16.1)	4,071 (13.2)	21,766 (70.7)
>30.0 (Obese)	26,830	3,947 (14.7)	6,390 (23.8)	16,493 (61.5)
Previous live births				
None	53,628	11,749 (21.9)	8,750 (16.3)	33,129 (61.8)
1	41,453	10,108 (24.4)	8,206 (19.8)	23,139 (55.8)
≤ 2	33,035	7,896 (23.9)	7,541 (22.8)	17,598 (53.3)
Unknown	663	53 (8.0)	80 (12.1)	530 (79.9)
Maternal Age				
< 20	12,367	2,711 (21.9)	2,744 (22.2)	6,912 (55.9)
20-29	67,114	14,914 (22.2)	13,040 (19.4)	39,160 (58.4)

[1] GWG: Gestational Weight Gain

[2] BMI: Body Mass Index

Table 2 (Continued)				
30-39	45,995	11,359 (24.7)	8,153 (17.7)	26,483 (57.6)
40-49	3,243	809 (24.9)	628 (19.4)	1,806 (55.7)
Unknown	60	13 (21.7)	12 (20.0)	35 (58.3)
Education				
< High School	20,594	4,693 (22.8)	5,383 (26.1)	10,518 (51.1)
High School Graduate	34,644	7,507 (21.7)	7,260 (21.0)	19,877 (57.4)
College	59,299	13,671 (23.1)	9,802 (16.5)	35,826 (60.4)
Graduate School	13,605	3,815 (28.0)	1,964 (14.4)	7,826 (57.5)
Unknown	637	120 (18.8)	168 (26.4)	349 (54.8)
WIC Recipient				
Yes	49,556	10,321 (20.8)	10,837 (21.9)	28,398 (57.3)
No	77,382	19,035 (24.6)	13,342 (17.2)	45,005 (58.2)
Unknown	1,841	450 (24.4)	398 (21.6)	993 (54)
Married				
Yes	75,703	18,967 (25.0)	13,382 (17.7)	43,354 (57.3)
No	52,652	10,749 (20.4)	11,085 (21.1)	30,818 (58.5)
Unknown	424	90 (21.2)	110 (26.0)	224 (52.8)
Race/Ethnicity				
Non-Hispanic				
White	91,608	21,871 (23.9)	15,938 (17.4)	53,798 (58.7)
Black	18,012	3,488 (19.4)	3,920 (21.7)	10,604 (58.9)
Asian	4,627	1,376 (29.7)	1,108 (24.0)	2,143 (46.3)
Other/Unknown	2,401	509 (21.2)	509 (21.2)	1,383 (57.6)
Hispanic	12,131	2,561 (21.1)	3,102 (25.6)	6,468 (53.3)

Table 3. Smoking status by maternal/socio-demographic factors

Covariates	N (%) 124,807 (100)	Non-Smokers 96,714 (77.5)	Smokers 16,180 (13.0)	Pre-preg Quitters 7,675 (6.1)	1st Tri Quitters 3,034 (2.4)	2nd Tri Quitters 1,204 (1.0)
Pre-pregnancy BMI						
< 18.5 (Underweight)	5,309	3,546 (66.8)	1,131 (21.3)	361(6.8)	187 (3.5)	84 (1.6)
18.5 - 24.9 (Normal Weight)	63,752	50,214 (78.8)	7,636 (12.0)	3,833 (6.0)	1,481 (2.3)	588 (0.9)
25.0 - 29.9 (Overweight)	29,803	23,307(78.2)	3,696 (12.4)	1,850 (6.2)	684 (2.3)	266 (0.9)
>30.0 (obese)	25,943	19,647 (75.7)	3,717 (14.3)	1,631 (6.3)	682 (2.6)	266 (1.0)
Previous live births?						
None	52,085	39,762 (76.3)	5,718 (11.0)	4,325 (8.3)	1,676 (3.2)	604 (1.2)
1	40,240	31,798 (79.0)	5,146 (12.8)	2,153 (5.3)	796 (2.0)	347 (0.9)
≤ 2	31,866	24,651 (77.4)	5,246 (16.5)	1,169 (3.7)	551 (1.7)	249 (0.8)
Maternal Age						
< 20	11,732	8,301 (70.8)	1,953 (16.6)	809 (6.9)	477 (4.1)	192 (1.6)
20-29	64,840	46,541 (71.8)	10,644 (16.4)	4,893 (7.5)	1,983 (3.1)	779 (1.2)
30-39	45,017	39,016 (86.7)	3,342 (7.4)	1,884 (4.2)	550 (1.2)	225 (.5)
40-49	3,160	2,808 (88.9)	235 (7.4)	86 (2.7)	23 (0.7)	8 (0.3)
Education						
< High School	19,544	13,383 (68.5)	4,460 (22.8)	923 (4.7)	531 (2.7)	247 (1.3)
High School Grad	33,158	21,762 (65.6)	7,244 (21.8)	2,477 (7.5)	1,177 (3.6)	498 (1.5)
College	58,018	47,998 (82.7)	4,326 (7.5)	3,975 (6.8)	1,272 (2.2)	447 (0.8)
Graduate School	13,531	13,130 (97.0)	80 (0.6)	269 (2.0)	42 (0.3)	10 (0.1)
Married						
Yes	74,413	65,039 (87.4)	4,506 (6.1)	3,636 (4.9)	920 (1.2)	312 (0.4)
No	50,003	31,447 (62.9)	11,542 (23.1)	4,024 (8.0)	2,103 (4.2)	887 (1.8)
WIC Recipient						
Yes	47,177	31,352 (66.5)	10,227 (21.7)	3,232 (6.8)	1,629 (3.4)	737 (1.6)
No	75,919	63,975 (84.3)	5,768 (7.6)	4,360 (5.7)	1,366 (1.8)	450 (0.6)

Table 3 (Continued)						
Race/Ethnicity						
Non-Hispanic						
White	89,452	66,466 (74.3)	13,392 (15.0)	6,254 (7.0)	2,399 (2.7)	941 (1.0)
Black	17,001	14,131 (83.1)	1,685 (9.9)	685 (4.0)	345 (2.0)	155(0.9)
Asian	4,530	4,379 (96.7)	63 (1.4)	65 (1.4)	21 (0.5)	2 (0.0)
Other	2,249	1,810 (80.5)	260 (11.6)	113 (5.0)	45 (2.0)	21 (0.9)
Hispanic	11,575	9,928 (85.8)	780 (6.7)	558 (4.8)	224 (2.0)	85 (0.7)

Table 4. Association between excess GWG & smoking status: Results from crude & adjusted logistic regression testing the full & reduced model

Exposure & All Covariates	*Crude OR (95% CI)*	*Full Model: Adjusted OR (95% CI) N = 93,684*	*Reduced Model: Adjusted OR (95% CI) N = 94,733*
Pre-pregnancy BMI			
< 18.5 (Underweight)	*Referent*	*Referent*	*Referent*
18.5 - 24.9 (Normal)	1.94 (1.82, 2.07)**[3]	2.06 (1.92, 2.21)**	2.05 (1.92, 2.2)**
25.0 - 29.9 (Overweight)	4.67 (4.36, 5.00)**	5.12 (4.75, 5.52)**	5.12 (4.75, 5.51)**
>30.0 (obese)	4.45 (4.15, 4.77)**	4.75 (4.40, 5.12)**	4.77 (4.42, 5.14)**
$\chi^2_{(df)}$ Test	**$\chi^2_{(3)}$ = 4288.2 p < 0.0001**	**$\chi^2_{(3)}$ = 3921.2 p < 0.0001**	**$\chi^2_{(3)}$ = 4019.8 p < 0.0001**
Smoking Status			
Non-Smokers	*Referent*	*Referent*	*Referent*
Smokers	1.04 (0.99, 1.09)	1.04 (0.99, 1.09)	1.05 (1.00, 1.10)*[4]
Pre-Pregnancy Quitters	1.64 (1.55, 1.75)**	1.56 (1.46, 1.66)**	1.56 (1.47,1.67)**
1st Trimester Quitters	1.54 (1.40, 1.69)**	1.47 (1.31, 1.60)**	1.46 (1.23, 1.70)**
2nd Trimester Quitter	1.46 (1.26, 1.70)**	1.44 (1.23, 1.69)**	1.44 (1.23, 1.69)**
$\chi^2_{(df)}$ Test	**$\chi^2_{(4)}$ = 343.2 p < 0.0001**	**$\chi^2_{(4)}$ = 234.8 p < 0.0001**	**$\chi^2_{(4)}$ = 243.1 p < 0.0001**
Previous live births?			
None	*Referent*	*Referent*	*Referent*
1	0.81 (0.79, 0.84)**	0.78 (0.75, 0.81)**	0.78 (0.76, 0.81)**
≤ 2	0.79 (0.76, 0.82)**	0.73 (0.70, 0.76)**	0.74 (0.71, 0.76)**
$\chi^2_{(df)}$ Test	**$\chi^2_{(2)}$ = 250.2 p < 0.0001**	**$\chi^2_{(2)}$ = 282.2 p < 0.0001**	**$\chi^2_{(2)}$ = 313.5 p < 0.0001**

[3] **Odds ratio is statistically significant ($p < 0.001$)

[4] *Odds ratio is statistically significant ($p < 0.05$)

Table 4 (Continued)			
Maternal Age			
< 20	*Referent*	*Referent*	*Dropped*
20-29	1.03 (0.98, 1.08)	1.05 (0.99, 1.11)	
30-39	0.91 (0.87, 0.96)**	1.06 (0.98, 1.13)	
40-49	0.88 (0.80, 0.96)*	0.98 (0.87, 1.09)	
$\chi^2_{(df)}$ **Test**	$\chi^2_{(3)}$ **= 72.5 p < 0.0001**	$\chi^2_{(3)}$ **= 5.0 p = 0.17**	
Education			
< High School	*Referent*	*Referent*	*Referent*
High School Grad	1.18 (1.13, 1.23)**	1.15 (1.10, 1.21)**	1.17 (1.12, 1.23)**
College	1.17 (1.12, 1.22)**	1.24 (1.18, 1.30)**	1.25 (1.20, 1.31)**
Graduate School	0.91 (0.87, 0.96)**	1.16 (1.08, 1.24)**	1.17 (1.10, 1.25)**
$\chi^2_{(df)}$ **Test**	$\chi^2_{(3)}$ **= 178.7 p < 0.0001**	$\chi^2_{(3)}$ **= 73.0 p < 0.0001**	$\chi^2_{(3)}$ **= 93.7 p < 0.0001**
Married			
No	*Referent*	*Referent*	*Referent*
Yes	0.80 (0.77, 0.82)**	0.86 (0.82, 0.89)**	0.85 (0.82, 0.88)
$\chi^2_{(df)}$ **Test**	$\chi^2_{(1)}$ **= 225.1 p < 0.0001**	$\chi^2_{(1)}$ **= 54.9 p < 0.0001**	$\chi^2_{(1)}$ **= 72.65 p < 0.0001**
WIC Recipient			
Yes	*Referent*	*Referent*	*Dropped*
No	1.16 (1.13, 1.20)**	1.04 (0.99, 1.08)	
$\chi^2_{(df)}$ **Test**	$\chi^2_{(1)}$ **= 117.2 p < 0.0001**	$\chi^2_{(1)}$ **= 3.7 p = 0.55**	
Race/Ethnicity			
Non-Hispanic			
White	*Referent*	*Referent*	*Referent*
Black	1.24 (1.19, 1.29)**	1.05 (1.00, 1.10)*	1.05 (1.00, 1.11)*
Hispanic	1.03 (0.98, 1.08)	1.01 (0.96, 1.07)	1.02 (0.96, 1.07)
$\chi^2_{(df)}$ **Test**	$\chi^2_{(2)}$ **= 100.84 p < 0.0001**	$\chi^2_{(2)}$ **= 3.9 p = 0.14**	$\chi^2_{(2)}$ **= 4.5 p = 0.11**

Table 5. Adjusted association between excess GWG & smoking status stratified by race: Results from adjusted logistic regression using the reduced model

Exposure & Significant Covariates	*Overall Adjusted OR (95% CI) N = 94,733*	*Adjusted OR (95% CI) Among Non-Hispanic Whites N = 73,329*	*Adjusted OR (95% CI) Among Non-Hispanic Blacks N = 12,931*	*Adjusted OR (95% CI) Among Hispanic N = 8,473*
Pre-pregnancy BMI				
< 18.5 (Underweight)	*Referent*	*Referent*	*Referent*	*Referent*
18.5 - 24.9 (Normal)	2.05 (1.92, 2.2)**[5]	2.10 (1.94, 2.27)**	1.89 (1.55, 2.31)**	1.91 (1.53, 2.39)**
25.0 - 29.9 (Overweight)	5.12 (4.75, 5.51)**	5.49 (5.04, 5.97)**	4.39 (3.56, 5.41)**	3.70 (2.92, 4.68)**
>30.0 (obese)	4.77 (4.42, 5.14)**	4.89 (4.48, 5.33)**	4.43 (3.58, 5.46)**	4.14 (3.24, 5.28)**
Smoking Status				
Non-Smokers	*Referent*	*Referent*	*Referent*	*Referent*
Smokers	1.05 (1.00, 1.10)*[6]	1.04 (0.98, 1.09)	1.11 (0.96, 1.29)	1.24 (1.01, 1.53)*
Pre-Pregnancy Quitters	1.56 (1.47,1.67)**	1.61 (1.50, 1.72)**	1.32 (1.07, 1.64)*	1.33 (1.06, 1.67)*
1st Trimester Quitters	1.46 (1.23, 1.70)**	1.50 (1.34, 1.68)**	1.21 (0.91, 1.62)	1.41 (0.98, 2.02)
2nd Trimester Quitter	1.44 (1.23, 1.69)**	1.41 (1.18, 1.67)**	1.93 (1.17, 3.19)*	1.17 (0.66, 2.09)
Previous live births?				
None	*Referent*	*Referent*	*Referent*	*Referent*
1	0.78 (0.76, 0.81)**	0.78 (0.75, 0.81)**	0.86 (0.78, 0.96)**	0.72 (0.64, 0.81)**
≤ 2	0.74 (0.71, 0.76)**	0.72 (0.69, 0.75)**	0.86 (0.77, 0.95)**	0.70 (0.62, 0.78)**

[5] **Odds ratio is statistically significant ($p < 0.001$)

[6] *Odds ratio is statistically significant ($p < 0.05$)

Table 5 (Continued)				
Education				
< High School	*Referent*	*Referent*	*Referent*	*Referent*
High School Grad	1.17 (1.12, 1.23)**	1.24 (1.17, 1.32)**	1.08 (0.97, 1.21)	1.03 (0.91, 1.16)
College	1.25 (1.20, 1.31)**	1.33 (1.26, 1.41)**	1.15 (1.02, 1.28)*	1.03 (0.91, 1.17)
Graduate School	1.17 (1.10, 1.25)**	1.24 (1.15, 1.33)**	1.17 (0.93, 1.49)	0.88 (0.67, 1.15)
Married				
No	*Referent*	*Referent*	*Referent*	*Referent*
Yes	0.85 (0.82, 0.88)	0.84 (0.80, 0.88)**	0.92 (0.82, 1.02)	0.84 (0.75, 0.94)
Race/Ethnicity				
Non-Hispanic				
White	*Referent*	*Not Applicable*	*Not Applicable*	*Not Applicable*
Black	1.05 (1.00, 1.10)*			
Hispanic	1.02 (0.96, 1.07)			

Table 6. Adjusted association between excess GWG & smoking status stratified by prepregnancy BMI: Results from adjusted logistic regression using the reduced model

Exposure & Significant Covariates	*Overall Adjusted OR (95% CI)*	*Adjusted OR (95% CI) Among Underweight N = 3,548*	*Adjusted OR (95% CI) Among Normal Weight N = 47,579*	*Adjusted OR (95% CI) Among Overweight N = 24,566*	*Adjusted OR (95% CI) Among Obese N = 19,040*
Pre-pregnancy BMI					
< 18.5 (Underweight)	*Referent*				
18.5 - 24.9 (Normal)	2.05 (1.92, 2.2)**	*Not Applicable*	*Not Applicable*	*Not Applicable*	*Not Applicable*
25.0 - 29.9 (Overweight)	5.12 (4.75, 5.51)**				
>30.0 (obese)	4.77 (4.42, 5.14)**				
Smoking Status					
Non-Smokers	*Referent*	*Referent*	*Referent*	*Referent*	*Referent*
Smokers	1.05 (1.00, 1.10)*	1.01 (0.85, 1.21)	1.12 (1.04, 1.19)*	0.87 (0.79, 0.97)*	1.06 (0.94, 1.18)
Pre-Pregnancy Quitters	1.56 (1.47,1.67)**	1.60 (1.24, 2.05)**	1.63 (1.50, 1.78)**	1.41 (1.21, 1.63)**	1.46 (1.24, 1.72)**
1st Trimester Quitters	1.46 (1.23, 1.70)**	1.46 (1.05, 2.04)*	1.60 (1.40, 1.82)**	1.29 (1.02, 1.63)*	1.22 (0.97, 1.54)
2nd Trimester Quitter	1.44 (1.23, 1.69)**	1.29 (0.79, 2.10)	1.40 (1.14, 1.72)*	1.68 (1.10, 2.52)*	1.49 (0.99, 2.25)
Previous live births?					
None	*Referent*	*Referent*	*Referent*	*Referent*	*Referent*
1	0.78 (0.76, 0.81)**	0.82 (0.70, 0.96)*	0.83 (0.79, 0.86)**	0.68 (0.63, 0.74)**	0.73 (0.66, 0.79)**
≤ 2	0.74 (0.71, 0.76)**	0.90 (0.75, 1.08)	0.82 (0.78, 0.86)**	0.58 (0.53, 0.63)**	0.67 (0.61, 0.74)**
Education					
< High School	*Referent*	*Referent*	*Referent*	*Referent*	*Referent*
High School Grad	1.17 (1.12, 1.23)**	0.98 (0.81, 1.17)	1.23 (1.16, 1.31)**	1.21 (1.10, 1.34)**	0.99 (0.88, 1.12)
College	1.25 (1.20, 1.31)**	0.97 (0.80, 1.18)	1.28 (1.21, 1.36)**	1.42 (1.29, 1.57)**	1.05 (0.93, 1.18)
Graduate School	1.17 (1.10, 1.25)**	0.76 (0.54, 1.06)	1.11 (1.03, 1.20)*	1.58 (1.36, 1.83)**	1.37 (1.13, 1.65)*
Married					
No	*Referent*	*Referent*	*Referent*	*Referent*	*Referent*
Yes	0.85 (0.82, 0.88)	0.77 (0.66, 0.91)*	0.84 (0.80, 0.88)**	0.90 (0.83, 0.97)*	0.85 (0.78, 0.93)**

Table 6 (Continued)					
Race/Ethnicity					
Non-Hispanic	*Referent*	*Referent*	*Referent*	*Referent*	*Referent*
White	1.05 (1.00, 1.10)*	1.06 (0.85, 1.33)	1.05 (0.98, 1.13)	1.01 (0.93, 1.13)	1.10 (0.99, 1.22)
Black	1.02 (0.96, 1.07)	1.13 (0.89, 1.43)	1.09 (1.01, 1.17)*	0.88 (0.78, 0.98)*	1.0 (0.88, 1.14)
Hispanic					

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